

Research in Upper Ocean Predictability

Secretary of the Navy Research Chair in Oceanography

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LONG-TERM GOALS

The goal of this research is to develop a predictive capability for the upper ocean circulation and atmospheric interactions using numerical models.

OBJECTIVES

The research objectives at COAPS are to develop ocean prediction capability and understanding of ocean physical processes, with particular interest in climate variability, connecting the shelf circulation to the deep ocean, evaluating models against available observations, and developing assimilation techniques to be used in these models. In addition, we are continuing the task of preparing long-term global surface fluxes and high-resolution data sets of surface winds for forcing regional ocean models.

This special ONR Grant is the base support for the FSU Center for Ocean-Atmospheric Prediction Studies. Other agencies who contribute are NASA, NSF, and NOAA.

APPROACH

We are using a suite of models forced by surface thermodynamic fluxes and rivers, with very fine horizontal resolution and realistic basin geometries. The models' vertical coordinates vary from reduced gravity or isopycnal formulations of the Navy Layered Ocean Model to hybrid high-resolution vertical coordinates in the Navy Coastal Ocean Model. The key individuals participating in this work include Ken-ichi Mizoguchi (North Atlantic modeling), Andrea Mask (model nesting), Drs. Steve Morey and Jorge Zavala (regional ocean modeling), Dr. Mark Bourassa (air-sea fluxes), all supervised by Dr. James O'Brien. Much of the modeling work is done in cooperation with the Naval Research Laboratory in Stennis, MS. These projects are also being used to train students as successful oceanographers and meteorologists.

WORK COMPLETED

1. Regional ocean models can now be nested within a large-scale model with a dissimilar vertical grid by treating each vertical mode separately.

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2. Decadal variability of deep convection in the North Atlantic Ocean has been examined with a multi-decadal simulation using an ice-ocean coupled model.
3. A high-resolution simulation of the Gulf of Mexico has been developed using the Navy Coastal Ocean Model.
4. Hybrid QuikSCAT-NWP wind products have been developed for forcing our Gulf of Mexico model, to create products that have the improved accuracy and spatial resolution of the scatterometer winds, with the better temporal sampling of the NWP product. Each product has distinct strengths and weaknesses. We plan to examine the impacts of these shortcomings in the Gulf of Mexico model. Techniques to combine satellite and in-situ observations to create flux products are also being developed.
5. We participated in the SEAFLUX assessment of state-of-the-art flux algorithms.

RESULTS

1. This work focuses on developing a unique open boundary condition to be used when passively forcing a regional ocean model with output from a large-scale (typically isopycnal) model. Currently in ocean modeling only barotropic information is being passed in this situation but much of the interesting physics of the ocean is found in the baroclinic modes. The new method allows the passing of baroclinic information by breaking the boundary data into the barotropic and baroclinic normal modes using the vertical standing mode technique as described by Philander (1990). Once the modal information is calculated on both domains the two are combined using standard radiation boundary condition techniques. This is done for each modal component separately. Once the radiation boundary condition is applied, the modes are recombined to obtain the new boundary value for the regional model.
2. Forty-three years of output from an ice-ocean coupled model are used to investigate the decadal variability in the Labrador Sea (Mizoguchi et al., 1999). Propagating Complex Empirical Orthogonal Function analysis yields a mode (20% of the variance) consisting of alternating warm and cold temperature anomalies propagating from the Labrador Sea eastward with an approximate 11-14 year period. These anomalies penetrate from the subsurface to depth in a similar manner as a convective event (Figure 2). The location of the convective events coincides with that estimated from observations, off the eastern Labrador coast. The strongest convection events occur following a preconditioned state in autumn in which the Labrador Sea isopycnals are domed near the surface. The anomalies are identified along their journey in the North Atlantic Ocean as they propagate as Rossby waves to the Gulf Stream region.
3. The Navy Coastal Ocean Model (NCOM) is used to simulate at $1/20^\circ$ the Gulf of Mexico and northern Caribbean. The model employs a hybrid z-level and sigma (terrain following) vertical coordinate system that is useful for simulating shallow water dynamics on the continental shelf, as well as open ocean dynamics in the deep basin. The model is well suited for studies of cross shelf exchange of water and the influence of offshore ocean dynamics, i.e. the loop current and loop current eddies, on the continental shelf circulation. The model is forced by open boundary flow, air-sea fluxes of heat, freshwater, momentum, and by time-varying freshwater input by rivers. The model is being used to evaluate the impact of forcing by wind data sets using the SeaWinds scatterometer aboard the NASA

QuikSCAT satellite combined with ETA atmospheric model data. The model is also being used to investigate the seasonal variability of the western boundary current along the Western Shelf of the Gulf of Mexico, cyclonic eddies along the shelf break of the Campeche Bank (Zavala, et al., 2001), and the response of the shelf circulation to energetic atmospheric forcing.

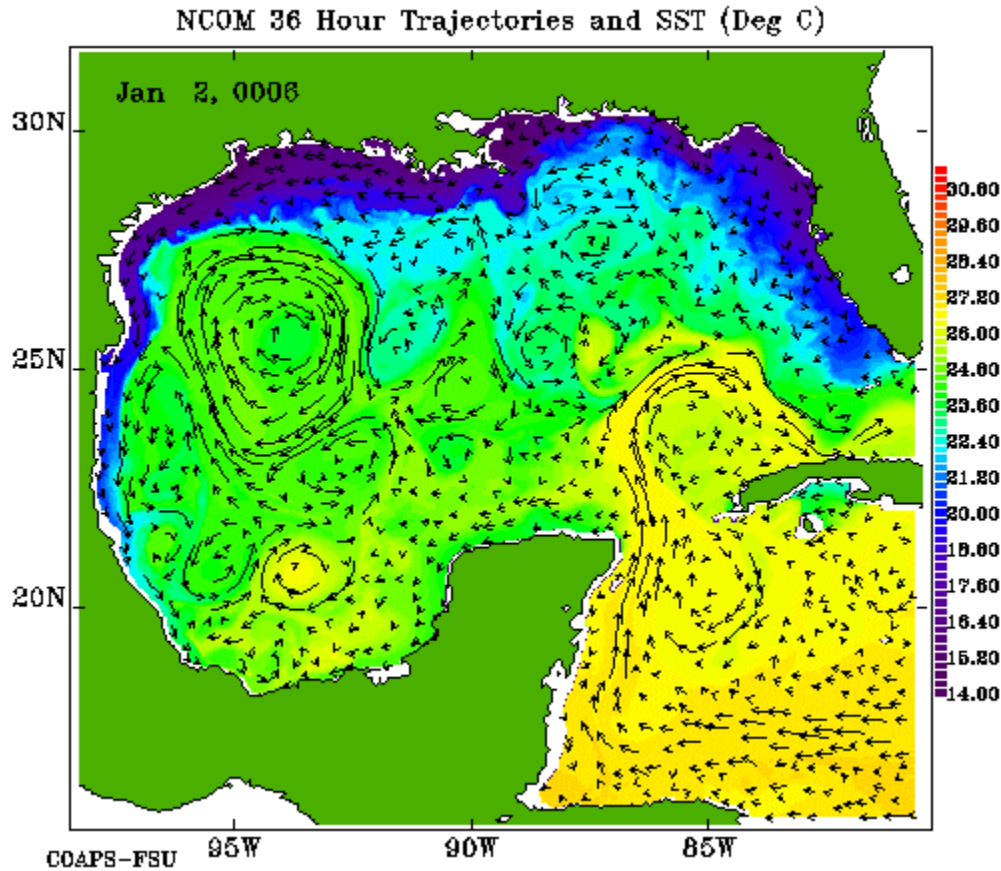


Figure 1 Surface 36-hour trajectories and temperature from the NCOM Gulf of Mexico simulation.

4. The hybrid wind products better capture the intensity of tropical cyclones, and mitigate the most serious of the spurious features along the edges of the satellite swaths. One product has a 12-hour interval between fields due to return period of the satellite. A second product uses more information from the ETA analyses to produce fields every 6 hours to better capture moving features such as strong frontal passages; however, the strength of cyclones is substantially reduced.
5. The SEAFUX flux algorithm assessment found that stresses (for $U_{10} < 7 \text{ ms}^{-1}$) estimated with our in-house flux algorithm (Bourassa et al. 1999) are closer to independent observations than the other state-of-the-art flux models. Another model developed from an earlier version of Bourassa et al. was found to have the best latent heat fluxes. A new model with the strengths of both these models is planned.

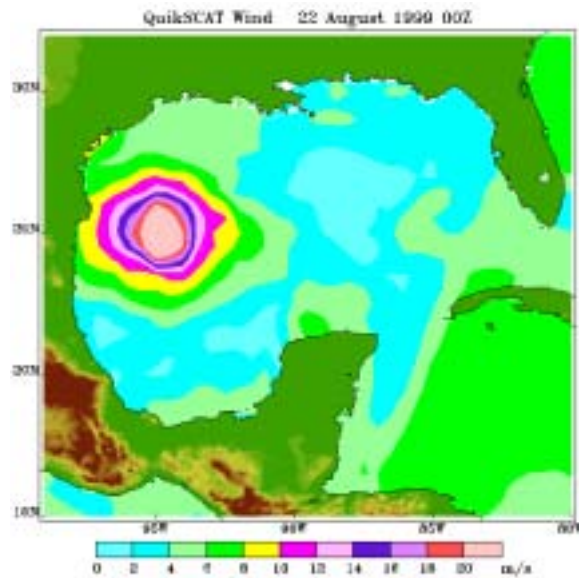


Figure 2 Wind speed from the SeaWinds scatterometer on QuikSCAT merged with the ETA analysis fields. This new data set better captures the structure of tropical cyclones and other episodic forcing events.

IMPACT/APPLICATIONS

Much of this successful project was conducted as a cooperative effort between Naval and academic personnel. Naval operations can use this information to better understand and predict the local marine environmental, enhance countermeasure measures and deployment, and improve acoustic detection capabilities.

TRANSITIONS

The knowledge gained in these studies has led to a greater understanding of the capabilities of the NRL ocean models, and how they can be used together. The model development work is expected to enhance prediction capabilities in strategic regions of interest. The related work has led to much more accurate forcing fields for ocean models.

RELATED PROJECTS

1. COAPS has previously managed an ONR Program in Environmental Numerical Modeling Support for Under-Represented Groups that placed 10-15 minority undergraduate science students in a laboratory-type work position with a mentoring professor. The goal was to convince these students to pursue graduate studies. Without the basic Secretary of Navy Grant, the ONR Program in Environmental Numerical Modeling Support for Under-Represented Groups would not have the infrastructure for the administration.
2. NSF supports the World Ocean Circulation Experiment Data Assembly Center and Special Analysis Center (WOCE DAC/SAC) for surface meteorology and surface fluxes. This center archives surface

meteorological observations from international research vessels as well as develops and validates high-quality surface flux fields, e.g. our tropical Pacific Ocean wind products for El Nino forecasts. Feedback to the vessel operators regarding the calculation of earth-relative winds from ships (Smith et al. 1999) has lead to great improvements in the accuracy of surface wind observations.

3. COAPS is part of the QuikSCAT and SeaWinds science team. We are using ocean vector surface wind observations from scatterometers to produce high quality fields of 'winds' (i.e., pseudostresses) and stresses. These fields have high spatial and temporal resolution (currently 1° and ½°, daily and six-hourly). These fields are used internally and with a wide range of colleagues, including modeling efforts at NRL (Stennis) and NASA Goddard. We have developed a fully objective technique for producing these gridded products (Pegion et al. 1999).

4. We are on the JASON science team. The altimetric sea surface heights are used to validate some of our ocean model results, including the propagation of Yanai waves, Kelvin Waves, and Rossby waves in several basins. The altimetric significant wave heights are used to modify wind-based stress fields.

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